ANALYSIS OF COMBUSTION AND EMISSION CHARACTERISTICS OF A DIESEL ENGINE FUELED WITH ETHANOL AS AN ALTERNATIVE FUEL

A REPORT FOR PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF TECHNOLOGY
IN
MECHANICAL ENGINEERING

BY

Mr ABHISHEK KUMAR SINGH
(110ME0333)

UNDER THE GUIDANCE OF
Prof. S MURUGAN

Department of Mechanical Engineering
National Institute of Technology
Rourkela

2014

NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA

CERTIFICATE

This is to certify that the thesis entitled "**Analysis of Combustion And Emission Characteristics of A Diesel Engine Fueled With Ethanol as An Alternate Fuel**" submitted by **Mr. Abhishek Kumar Singh** in partial fulfillment of the requirements for the award of Bachelor of Technology Degree in Mechanical Engineering at National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my guidance.

To the best of my knowledge the matter embodied in the thesis has not been submitted to any University for the award of any Degree or Diploma.

Date:

Prof. S Murugan
Department of Mechanical engineering
National Institute of Technology
Rourkela- 769008

ACKNOWLEDGEMENT

I am indebted to my guide **Prof. S. Murugan** for providing me an opportunity to work under his guidance. Like a true mentor, he motivated and inspired me through the entire duration of my work. I express my gratitude towards our HOD **Prof. K. P. Maity** for his support throughout the project work. I am also thankful to Prof. **S. K. Sahoo (**Project Coordinator) for smooth completion of the project curriculum.

I am also thankful to **Mr. Hari Shankar Bendu,** Research Scholar **of** Mechanical Engineering department for assisting me and guiding me throughout the project. I also extend my thanks to the supportive staff of Mechanical department for providing me all the necessary facilities to accomplish this project.

Last but not the least, I express my profound gratitude to the Almighty and my parents for their blessings and support without which this task could have never been accomplished.

ABHISHEK KUMAR SINGH
(110ME0333)

ABSTRACT

With the depletion of conventional fuel source at a very high rate and increasing environmental pollution has motivated extensive research in alternative fuel and in engine design. This project is an attempt towards finding the effect of alternate fuels (particularly ethanol) as a substitute over diesel in diesel engines to reduce diesel consumption. Thus ethanol, which can be manufactured naturally also, is introduced into the diesel engine with the purpose to replace some amount of diesel (conventional fuel) while performing the same amount of work. The effect of addition of ethanol into air intake manifold i.e. ethanol fumigation and diesel-ethanol blends on the emissions and the performance of a diesel engine (single cylinder) are experimentally investigated and compared. Also determination of an optimum percentage of ethanol which gives better performance and lower emissions was attempted. Experiments were carried out in a single cylinder, four strokes, and direct injection Kirloskar diesel engine. The test fuel used was Ethanol blended with diesel. The blending was carried out in volume percentages of ethanol and diesel. It was concluded that E20D80 is the best blending ratio and it showed the best results.

CONTENTS:

List of Figures

List of Tables

CHAPTER 1.

INTRODUCTION

INTRODUCTION

With depletion of conventional fuel (like petrol and diesel) at a tremendous rate and increasing environmental pollution has led to encouragement of research in alternative fuels and engine design. Experimental works aimed at good fuel economy and lower tailpipe emissions changes the operating parameters which is a time and money consuming method. The depleting fuel reserves, global warming and increasing cost of crude oil caused due to ever increasing CO_2 emissions and smoke emissions are growing concerns and tougher questions are being asked about sustainable development. This project is an attempt towards finding the effect of alternate fuels (particularly ethanol) as a substitute over diesel in diesel engines to reduce diesel consumption.

Another reason for alternate fuel development is the fact that huge percentage of crude-oil is imported from other countries that control bigger oil fields. In the present scenario many alternate fuels are used in limited quantities in automobiles.

An Outlook to the Global and Indian Scenario of Petroleum:

Global Scenario:

The use of oil and petroleum in the world is expected to increase from about 89 million barrels per day at present to 101 million barrels per day in 2017 and 120

in 2030 according to Energy Information Administration (EIA). Thus to meet this ever growing demand of oil, total petroleum supply has to increase by 31 mbpd in 3030. Also the crude oil price will increase from $31 per barrel in 2003 to $58 in 2030, and share of oil in total world energy use is predicted to fall from 39% to 33%.

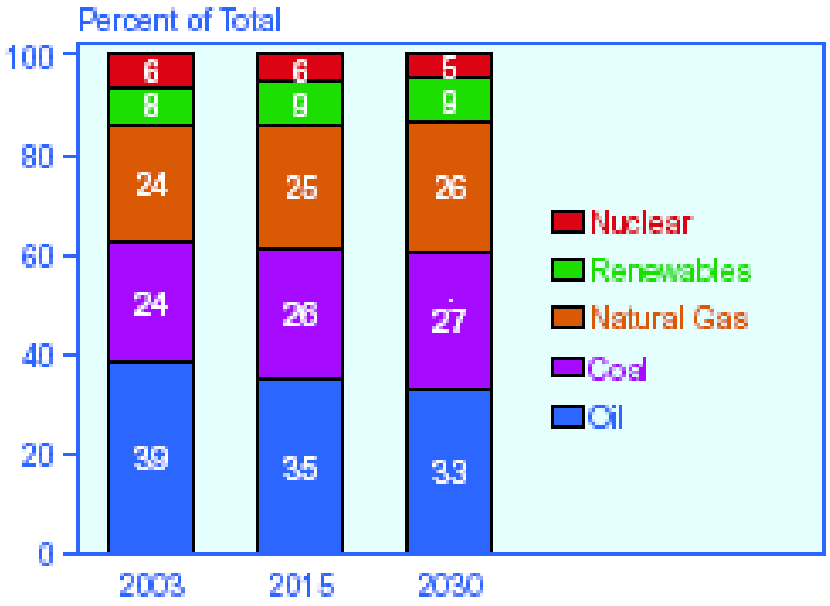

Figure 1:

Indian Scenario:

The petroleum industry in India contributes around 45% for providing energy source. The consumption of petroleum products in India is about 1/5th the world's average per capita consumption. The Indian oil consumption is expected to grow at a rate of 2.4% annually in comparison to that of 1.4% of world average.

The major factor which hinders the use of alternate fuels is the amount of additional cost which it adds for the user. Majority of alternate fuels are very costly right now since the amount used is very less. Most of these fuels will cost less if the quantity of their usage gets to the equal order of magnitude as diesel or gasoline. Another problem with alternate fuel is their scarcity of distribution stations where fuel can be available to the public. Thus for this problem to be overcome a huge network need to be build. But building of such a huge network is justified only when there are enough automobiles to make it profitable.

For a fuel to ignite in a diesel engine, it has to have a high cetane number or ability to self-ignite at large temperatures and pressures. There exists significant difference between gasoline, diesel and alcohol in the values of cetane number and auto ignition. A high cetane number causes a short ignition delay period, whereas lower cetane number results in longer ignition delay period. Alcohols are having lower cetane number as compare to that of diesel, which is unwanted when diesel engines are converted to alcohol. Thus either, additives like nitrate glycol can be added to alcohols, which increases their cetane number or various other injection methods can be used for injecting alcohol (ethanol) into diesel engine.

A. Alcohol-Diesel Emulsions:-

Because of the limited solubility of alcohols in diesel, stable emulsions should be formed which will allow it to be injected into the engine before separation occurs. Hydroshear emulsification unit could be used for producing emulsions of diesel-alcohols. However the emulsions are found to be stable only for 45 seconds. And 12% of alcohol (energy basis) is maximum amount. Other limitations include 1. Specific fuel consumption at lower speed increases, 2. High cost, 3. Instability

B. Fumigation:-

Fumigation is a process of injecting alcohol into diesel engine by means of a carburetor in inlet manifold. During the same time, the pump for diesel fuel operates at a reduced flow. In this process the function of the diesel fuel is to generate a pilot flame and alcohol is to be used as a fumigated fuel. Two major points must be noted before using this method. In low loads, amount of alcohol must be reduced for prevention of any misfire. On the other side, during high loads, amount of alcohol should also be decreased to avoid pre-ignition.

C. Dual Injection:-

In this system a small quantity of diesel is injected as pilot fuel for the ignition source. Also a large quantity of alcohol is introduced as a main fuel. It should be noted that pilot fuel has to be injected prior to the introduction of alcohol. Some ideal conclusions can be achieved by using this method. Thermal efficiency can be increased. Also at the same time, NO_x emission can be reduced. However, CO and HC emissions are the same. Moreover the system is also in need of two fuel systems, hence leading to higher cost. Meanwhile alcohols require additives for lubricity.

D. Heated surface:-

Alcohols can ignite also with the help of hot surfaces. Due to this reason, glow plugs could be utilized as source of ignition for the alcohols. In these systems, specific fuel consumption is depended upon glow-plug positions and temperatures. It should also be noted that the temperature of glow plugs should be varying with the load. Moreover these glow plugs become inefficient at a very high load. In addition to this, the specific fuel consumption is also greater than that of diesel.

E. Homogenous Charge Compression Ignition (HCCI):-

Engines using homogenous charge compression ignition is in the form of internal combustion where well-mixed fuel and are to be compressed to reach the auto-ignition temperature of the fuel. Instead of using a spark to ignite this mixture, the temperature and density of the mixture is raised due to compression. As soon as the entire mixture reaches the self-ignition temperature it reacts instantaneously. The main feature of HCCI is that ignition takes place at several places thus causing the air-fuel mixture to burn simultaneously. Hence there is no such direct initiator of combustion. This acts as a real challenge to control the combustion process. By using HCCI, gasoline like emissions can be achieved with diesel engine like efficiency.

CHAPTER 2.

LITERATURE SURVEY

LITERATURE SURVEY

Ethanol when blended with diesel, at various concentrations, could power a compression ignition engine [4]. However, according to chemical-physical properties, biodiesel-ethanol blends up to 15% ethanol could run a diesel engine just by increasing their flash point [5]. Various investigations are related with the influence of blending ethanol and mineral diesel fuel on the performance of engine and exhaust emissions. It showed an increase in brake thermal efficiency and increase in specific fuel consumption. It also showed a decrease in power of engine and a highly significant decrease in exhaust emissions as compared to that of diesel fuel [13].

The results of fumigation technique and blending techniques showed that they both have the same impact in affecting the emissions and performance, but the extent of improvement in using fumigation technique is higher than when blending is used. The difficulties that are mainly encountered while attempting use of alcohol in diesel engines are as follows:-

- Greater amount of alcohol fuel than diesel fuel is needed in terms of volume and mass [7].
- Greater percentages of alcohols would not mix with the diesel fuel, and hence use of alcohol –diesel blends are not feasible. In addition to this the blends

are not stable and they tend to separate in presence of small amount of water [10].

- ❖ Alcohols have a very low cetane number, whereas on the other hand diesel engines are known to prefer fuels with extremely high cetane number which can auto ignite easily and provide small ignition delay [12].
- ❖ Diesel fuels can also serve as lubricants for diesel engines. But alcohol fuel does not possess the same lubricating qualities [9, 10].
- ❖ There is a chance of vapor-look in the fuel delivery system [1].
- ❖ A danger of storage tank flammability exists because of low vapor pressure. Thus leakage of air into the storage tank could create a combustible mixture [1].
- ❖ Alcohol combustion produces more aldehydes in exhaust. If equal amount of alcohol fuel was to be consumed as diesel, then aldehyde emissions would become a serious pollution problem [1].
- ❖ Poor auto-ignition quality of alcohols is the cause for severe knocking tendency due to rapid burning of alcohol which is in vaporized form and the combustion quenching due to high latent heat of vaporization and thus resulting charge cooling [1].

Fumigation is that method through which alcohol is introduced to the engine by carbureting, injecting or vaporizing alcohol into the intake stream of air. This

process thus requires the addition of a carburetor, injector or a vaporizer, as well as a different fuel tank, controls and lines. The advantages of Fumigation technique are as follows:-

(i) This method needs a minimum modification towards the engine, as the injector of alcohol is placed at the intake manifold of air.

(ii) The fuel system of alcohol is different from the fuel system of diesel. Thus this type of flexibility enables the diesel engine, which is equipped with this system to be operated from diesel fuel. The engine can also be switch from diesel fuel operation to dual fuel operation and vice-versa through disconnecting and connecting the alcohol source with the injector.

(iii) Through fumigation process up to 50% of fuel energy could be provided by alcohol [14].

(iv) Also in case an engine is restricted in consumption of power/output due to smoke emissions, fumigation of ethanol could increase the output of power as alcohol tends to reduce smoke [11].

Replacement of diesel fuel entirely with the help of alcohol is too difficult, however alcohols of lower carbon chains with varying amounts and by various techniques in the diesel engines could be practically feasible (as a dual fuel operation).

In the category of liquid fuels alcohol is the main alternative. Alcohols are a feasible option because they can be obtained from both manufactured as well as natural

sources. Ethanol (ethyl alcohol) and Methanol (methyl alcohol) are the most promising kinds of alcohols. The advantages served by these alcohols are as follows:-

- Alcohols could be obtained from various sources, both manufactured and natural.
- Alcohols consist of lower sulphur-content.
- Alcohols have higher latent heat of vaporization due to which intake process becomes cooler. This causes an increase in the volumetric efficiency and the required work output in the compression stroke is reduced.
- Due to the burning of alcohols, more moles of exhaust gases are formed, which results in more power and higher pressure in the stroke of expansion [1].

Fuel Selection:

Alcohols of lower carbon chain are preferred because of their tendency for breaking the bond readily. Thus options available are as follows:-

Methanol/Ethanol/Butanol

While ethanol and methanol both could be obtained from natural gas or petroleum products, ethanol is attracting greater attention as it is considered a renewable resource, which can be easily obtained from starch or sugar present in crops and also in grains and sugarcane (agricultural products). Ethanol is very common in

nature as it is found wherever yeast finds a sugar solution like fruits which are overripe. Because of this most organisms are evolving and they are developing some amount of tolerance to ethanol. On the other hand methanol is still toxic. Production of butanol can also occur by fermentation of plants. However ethanol is given more preference because ethanol is biomass-fuel, which is addressing green house gas emissions (likeCO_2) and climate changes.

Another point of concern is that methanol has a greater tendency to mix and combine with water molecules present. This is the cause for local separation of alcohol from diesel, which further results in non- homogenous mixture. And methanol solubility is also limited in majority of diesel fuels.

Properties Analysis

The properties of diesel and ethanol are shown in the table below:

Properties	Diesel	Ethanol
Formula	$C_8 to\ C_{20}$	C_2H_5OH
Molecular Weight	200	46.07
Density	837.3	796
Specific Gravity	0.84	0.796
Boiling Point	$187^o - 343^o$	80^oC
Cetane Number	50-55	5-10
Viscosity	2.6–4.1 Centipoise	1.19 Centipoise
Lower Heating Value	42.686 MJ/kg	26.952 MJ/kg
Flash Point	66^oC	13^oC
Auto Ignition Temperature	316^oC	423^oC

Table 1:-

CHAPTER 3.

EXPERIMENTAL SETUP

EXPERIMENTAL SETUP:

A single cylinder, four strokes, direct injection Kirloskar diesel engine is used for the present study. The outline of the experimental setup is as shown in the figure and a detailed specification for the test engine is also provided in the table. The setup comprises of the following: a single cylinder, direct injection, air cooled, four strokes diesel engine which is coupled to electrical dynamometer. A Kistler pressure transducer (piezoelectric) of model: 5395A, a laptop, a charge amplifier and the crank angle encoder.

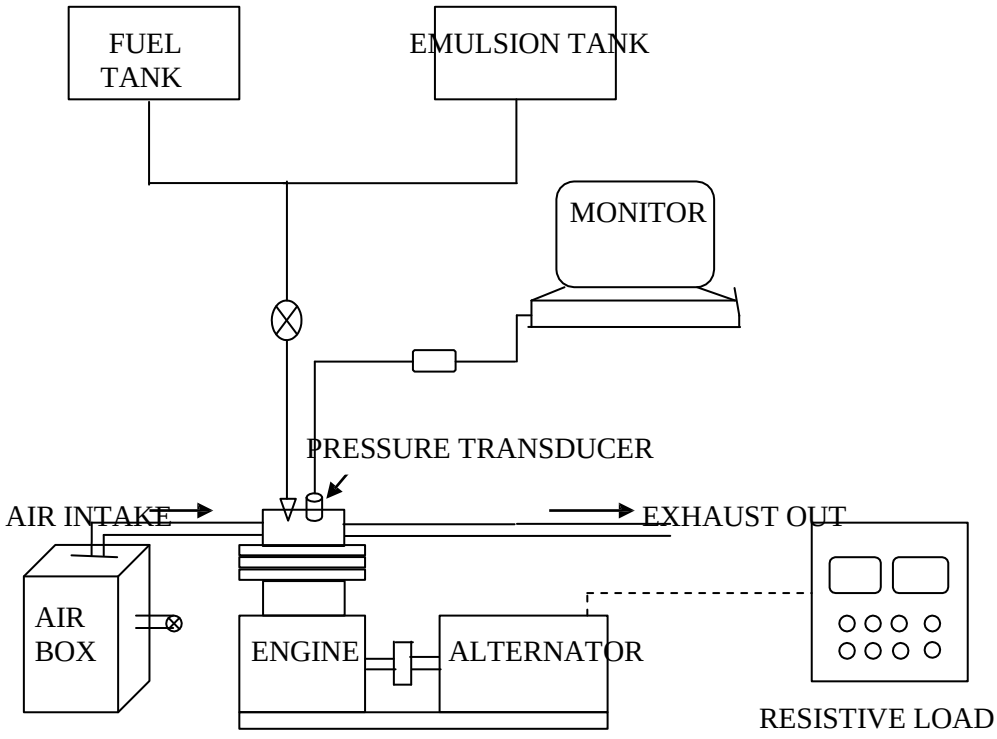

Figure 2, ***Schematic diagram of experimental setup***

The fuel consumption is to be measured by using a solenoid controlled automatic burette. The differential pressure sensor attached in air box is used for measuring the air consumption. For the purpose of damping out the pulsations which are produced from the engine, a surge tank is used. This is done to ensure a steady flow of air from the intake manifold. The engine speed is measured by fitting a non contact kind of sensor near the engine flywheel. For the purpose of data acquisition, 23 channel signal analyzers are used the data which is thus acquired is to be transferred and stored in personal laptop via Ethernet cable for performing offline analysis.

Table 2. Technical specifications of engine [12]

Make	Kirloskar
Model	TAF 1
Bore x Stroke	87.5 x 110 mm
Compression ratio	17.5:1
Type of piston	Bowl-in-piston
Number of valves	2
Rated power	4.4 kW
Rated speed	1500 rpm
Fuel injection Type	Pump-line-nozzle injection system
Nozzle type	Multi hole
No. of holes	3
Needle lift	0.25 mm
Diameter of Spray-hole	0.25 mm
Cone angle	110^{o}
Start of injection	23^{o} CA bTDC
Nozzle pressure (opening)	200 bar
Inlet valve at opening	4.5^{o} CA bTDC
Inlet valve at closing	35.5^{o} CA aBDC
Exhaust valve at opening	35.5^{o} CA bBDC
Exhaust valve at closing	4.5^{o} CA aTDC

Chapter 4

RESULTS AND DISCUSSION

Result and Disscussuions:

Ignition Delay vs. Load:

Ignition delay also known as preparatory phase in which small quantity of fuel is injected into the cylinder but it has not yet ignited. Ignition delay can be defined as the period from the start of injection to the period when the actual combustion (burning of fuel) starts. In CI engines, ignition delay influences the engine performance and its design. It possesses great importance because of its impact on knocking as well as combustion rate.

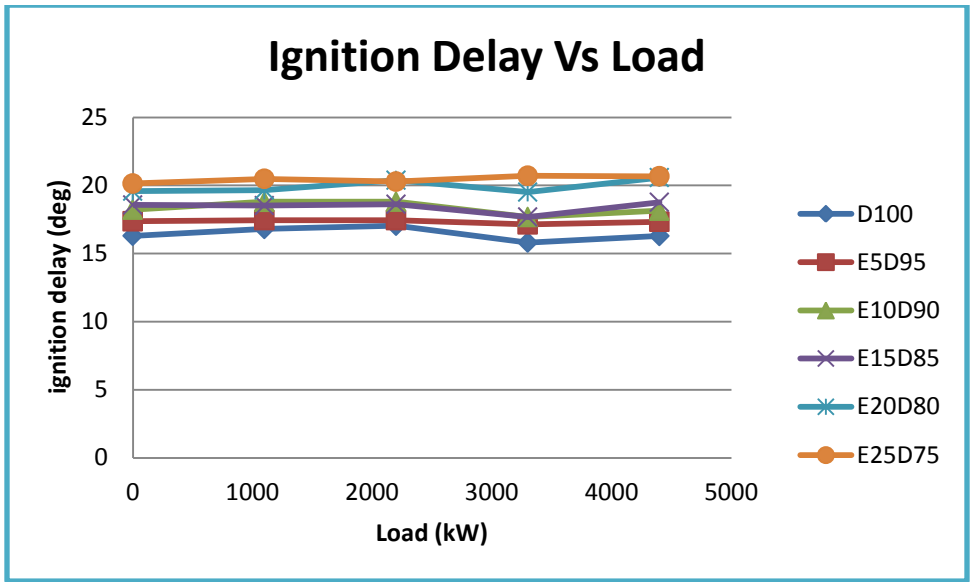

Figure 3:

The graph above shows the variation of ignition delay with respect to load. As the percentage of ethanol increases with the blend, the latent heat of vaporization increases which causes an increase in the ignition delay and thus increases the physical delay.

Combustion Duration:

It is the period between the start of combustion to the end of the combustion.

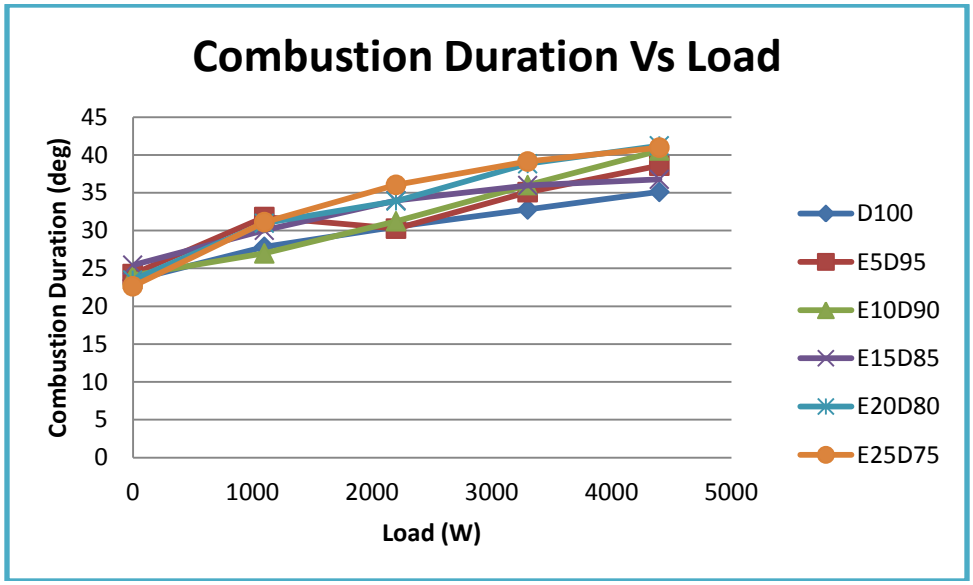

Figure 4:

From the above graph it is concluded that the combustion duration is maximum for E25D75 blend. This is due to longer ignition delay and high latent heat of vaporization of ethanol.

Maximum Pressure Vs Load:

In CI engines the maximum pressure is reached after TDC (Top Dead Center). The maximum pressure depends upon the distance from the TDC after which the combustion starts. Depending upon the maximum pressure reached, the amount of work which can be extracted from the engine could be found out. Thus greater is the maximum pressure achieved; higher is the amount of work extracted.

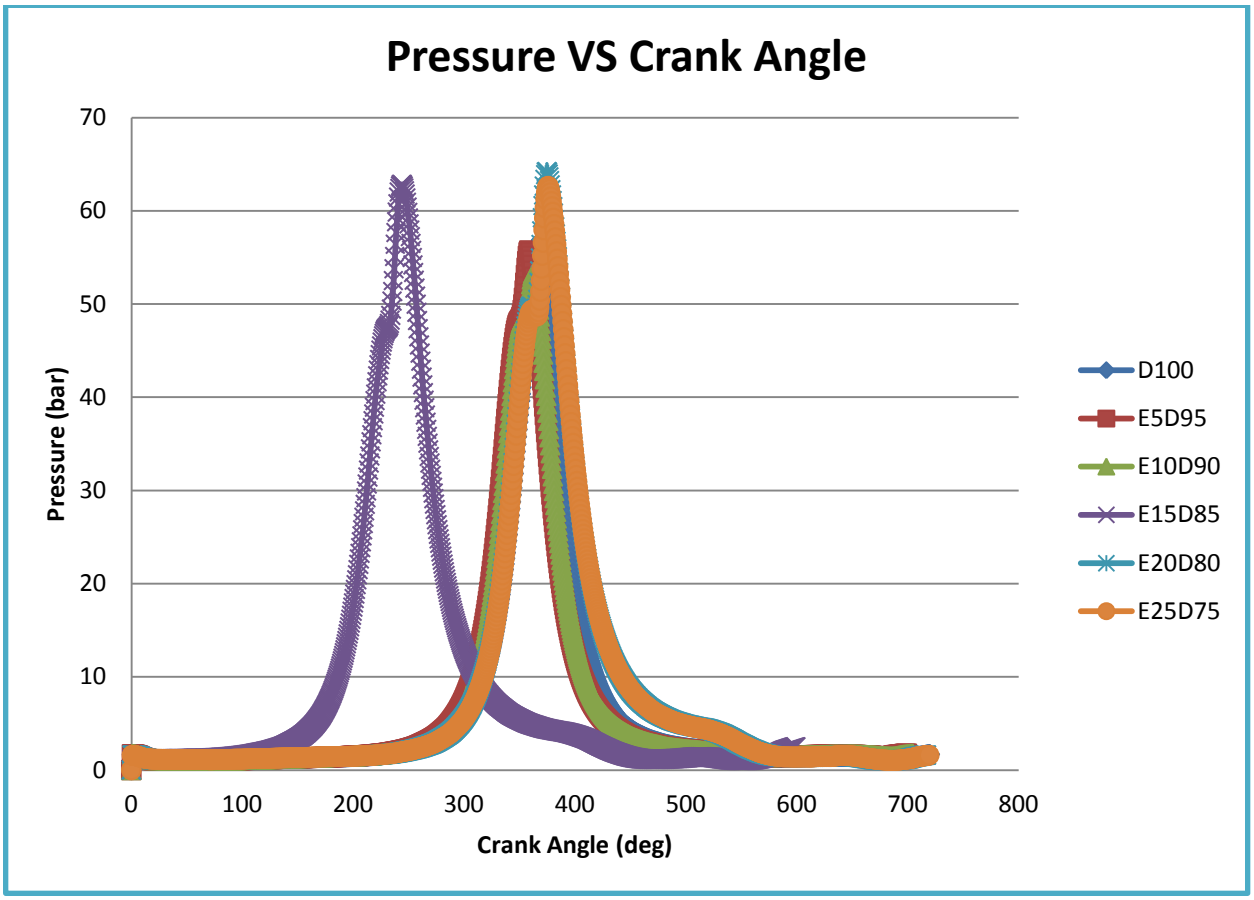

Figure 5:

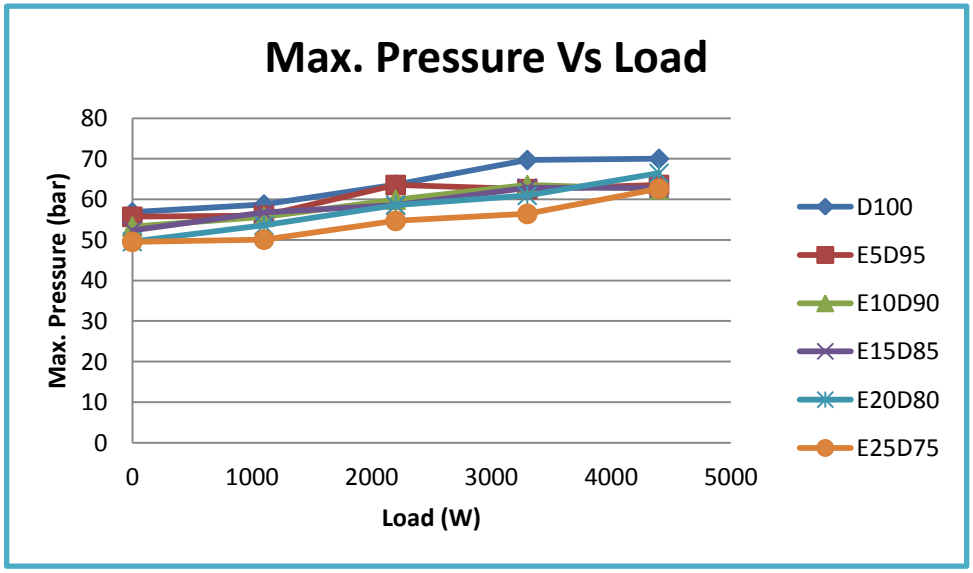

Figure 6:

From the above graph we find that the maximum pressure is reached for E20D80 blend at full load.

BRAKE SPECIFIC FUEL CONSUMPTION & BRAKE THERMAL EFFICIENCY:

Brake specific fuel consumption and brake thermal efficiency are inversely proportional to each other. Thus as the specific fuel consumption decreases, the brake thermal efficiency increases with load and vice-versa.

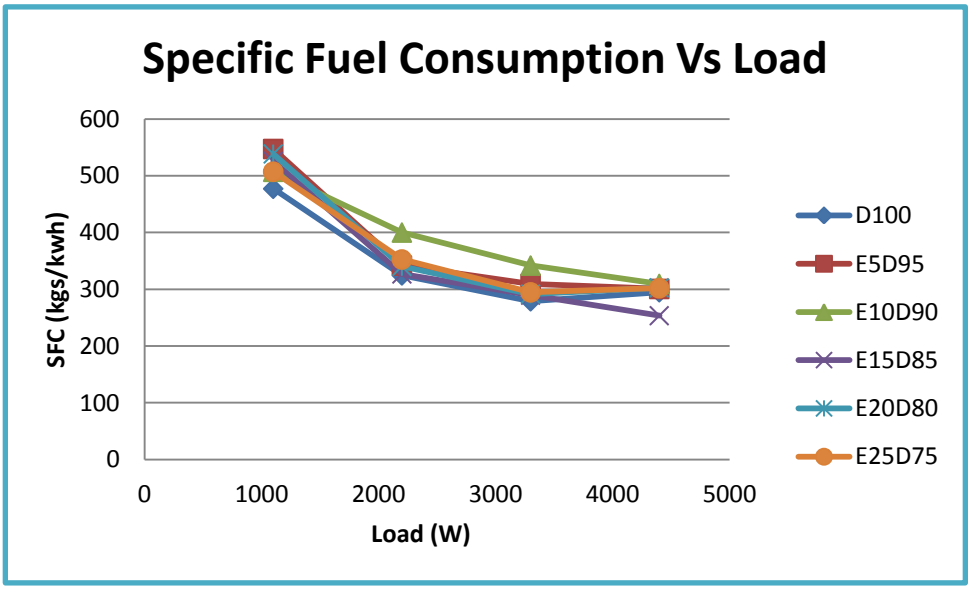

Figure 7:

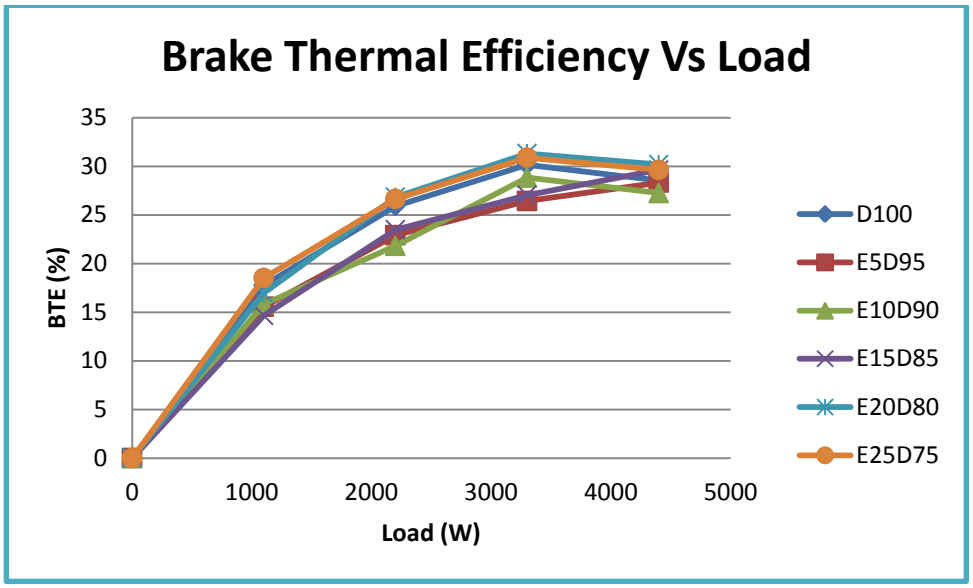

Figure 8:

From the above graph we can notice that the brake thermal efficiency is highest for E20D80 blend.

Chapter 5.

CONCLUSIONS:

Experiments were carried out in a single cylinder, four strokes, and direct injection Kirloskar diesel engine. The test fuel used was Ethanol blended with diesel. The blending was carried out in volume percentages of ethanol and diesel. For the present study ethanol blends ranging from 5% to 25% in steps of 5 with diesel.

- Ignition delay increased with increasing load. E20D80 showed the best results.
- Combustion duration is increasing with the increase in load. Combustion duration is maximum for E25D75 blend.
- Maximum pressure is increasing with the load. The maximum pressure is reached for E20D80 blend at the full load.
- Specific fuel consumption decreases with increase in the load and brake thermal efficiency increases with load. E20D80 shows the best result.

Thus from the above statements it can be concluded that E20D80 is the best blending ratio and it showed the best results.

CHAPTER 6

References

1. Ganesan V., Internal Combustion Engines. New Delhi, *Tata McGraw-Hill, 2009*
2. Physical and chemical properties of ethanol-diesel fuel blends.
3. Dorado MP, Arnal JM. The effect of a waste vegetable oil blend with diesel fuel on engine performance. *Trans ASAE 2002*
4. Riberio SK, Younes-Ibrahim PS. Global warming and transport in Brazil-ethanol alternative.
5. Torres-Jimenez E, SvolJsak-Jerman M, Gregorc A, Lisec I. Physical and chemical properties of ethanol – biodiesel blends for diesel energies. *Energy Fuels 2010.*
6. Hiesey JB, Lestz SS. Aqueous alcohol fumigation of a single cylinder DI diesel engine, *SAE Paper No. 811208, 1981*
7. Doann H-A. Alcohol fuels. Boulder, CO: *Westview Press, 1982*
8. Hayes TK, Savage LD, White RA, Sorenson SC. The effect of the fumigation of different ethanol proofs on a turbocharged diesel engine, *SAE Paper No. 880497, 1988*
9. Doann H-A. Alcohol fuels. Boulder, CO: *Westview Press, 1982.*
10. Broukhiyan EMH, Lestz SS. Ethanol fumigation of a light duty automotive diesel engine, *SAE Paper No 811209, 1981*.
11. Eugene EE, Bechtold RL, Timbario TJ, McCallum PW.State-of-the-art report on the use of alcohols in diesel engines. *SAE paperNo.840118, 1984.*
12. Broukhiyan EMH, Lestz SS. Ethanol fumigation of a light duty automotive diesel engine, *SAE Paper No 811209, 1981.*

*13.*XU BY, Qi YL, Zhang WB, Cai SL. Fuel properties and emissions characteristics of ethanol-diesel blend on small diesel engine.

*14.*The effect of alcohol fumigation on diesel engine performance and emissions. Energy conversion and Management 41 (2000) 389-399.